POLISHING ELEMENT

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 92131624, filed November 12, 2003.

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a polishing element. More particularly, the present invention relates to a polishing element for increasing the polishing rate of a fixed abrasive chemical-mechanical polishing operation.

Description of the Related Art

[0002] As semiconductor devices are miniaturized, a greater resolution is required in each photolithographic exposure and the accompanied depth of exposure is reduced. Hence, the planarity of wafer in each processing stage is more stringent. At present, the required degree of planarity in a wafer is produced by performing a chemical-mechanical polishing operation. Due to the versatility of anisotropic polishing, chemical-mechanical polishing operations have many applications. Chemical-mechanical polishing is routinely used in the planarization of wafer surface, the fabrication vertical and horizontal interconnects in a damascene structure, the formation of shallow trench isolation (STI) structures in front end manufacturing, the

production of advanced devices, the planarization of micro-electromechanical systems and the production of flat displays.

[0003] Chemical-mechanical polishing operation is a particularly important step in the fabrication of shallow trench isolation (STI) structures. Conventionally, slurry is used in the chemical-mechanical polishing of STI structures to remove the silicon oxide over the silicon nitride layer inside the active regions. However, polishing with slurry can hardly minimize the amount of dishing in the silicon oxide within the shallow trench. In recent years, a slurry-free polishing method known as fixed abrasive chemical-mechanical polishing has been developed. Instead of using slurry, polishing particles are fixed onto a polishing pad. In other words, the polishing pad has a surface with evenly distributed polishing particles resembling an abrasive cloth (or a piece of sandpaper). One major advantage of polishing with a fixed abrasive pad is the polishing selectivity between silicon oxide and silicon nitride and the high planarization efficiency so that dishing of the silicon oxide within the shallow trenches is greatly reduced.

[0004] Fig. 1 is a schematic cross-sectional view of a conventional foxed abrasive polishing element. A conventional fixed abrasive polishing element 100 comprises a polishing platen 130, a polishing sub-pad 120 and a polishing pad 110 sequentially stacked over each other. The polishing pad 110 is the fixed abrasive polishing pad. The polishing pad is formed by sprinkling abrasive particles evenly within a layer of binder. Wafer polishing is achieved through a relative motion between the wafer and the polishing element 100 after pressing the two together.

[0005] However, the aforementioned polishing element 100 has a few application problems. As the surface of a polishing object is gradually planarized, the

surface of the polishing pad 110 will become increasingly smooth and the polishing object will encounter some difficulties in removing the binder within the polishing pad 110. Consequently, the polishing rate will drop abruptly and some residual polishing material will stay on the polishing object.

[0006] In the fabrication of STI structures, the silicon oxide on the silicon nitride layer within the active region must be limited to a predetermined height level. This prevents the aforementioned drop in the polishing rate and the retention of silicon oxide residue due to the presence of a thick planarized silicon oxide layer (the polished material) on the wafer. Nevertheless, this narrows the gap-filling process window with silicon oxide.

[0007] Furthermore, in the fabrication of STI structures within the 90nm or sub-90nm range, process window for filling the gaps with silicon oxide will become too narrow. Therefore, the silicon oxide on the silicon nitride layer within the active region may exceed the predetermined height level leading to the aforementioned problems of the rapid drop in polishing rate and the retention of residual silicon oxide. In other words, the fixed abrasive chemical-mechanical polishing operation is unsuitable for fabricating 90nm or sub-90nm STI structures.

SUMMARY OF THE INVENTION

[0008] Accordingly, one object of the present invention is to provide a polishing element for increasing the polishing rate of a fixed abrasive chemical-mechanical polishing operation.

[0009] A second object of this invention is to provide a polishing element that can increase the polishing rate of a fixed abrasive chemical-mechanical polishing operation and reduce in process loading effect.

[0010] A third object of this invention is to provide a polishing element for performing a fixed abrasive chemical-mechanical polishing operation on a smaller shallow trench isolation (STI) structure and increasing the process window in the production of the STI structure.

[0011] To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides a polishing element. The polishing element comprises a polishing platen, a sub polishing pad and a polishing pad. The polishing sub-pad is set up over the polishing platen and the polishing pad is set up over the polishing sub-pad. A first surface of the polishing sub-pad is contacted to the polishing pad and a second surface of the polishing sub-pad is contacted to the polishing platen. One major aspect of the invention is that at least one of the first surface and the second surface of the polishing sub-pad is undulating.

[0012] In the aforementioned polishing element, both the first surface and the second surface of the polishing sub-pad are undulating.

[0013] This invention also provides an alternative polishing element. The polishing element comprises a polishing platen, a sub polishing pad and a polishing pad. The polishing sub-pad is set up over the polishing platen and the polishing pad is set up over the polishing sub-pad. A first surface of the polishing sub-pad is contacted to the polishing pad and a second surface of the polishing sub-pad is contacted to the polishing platen. Furthermore, a third surface of the polishing pad is contacted to the polishing

sub-pad and a fourth surface of the polishing platen is contacted to the polishing sub-pad. One major aspect of the invention is that one among the first surface, the second surface and the fourth surface is undulating.

[0014] In the aforementioned polishing element, both the first surface and the second surface of the polishing sub-pad are undulating.

[0015] This invention also provides a polishing platen for assembling with a polishing sub-pad and a polishing pad to form a polishing element. The polishing paten has a body, and one of the surfaces of the polishing platen is contacted to the polishing sub-pad. One major aspect of this invention is that the surface is undulating.

[0016] This invention also provides a polishing sub-pad for assembling with a polishing platen and a polishing pad to form a polishing element. The polishing sub-pad has a body, and a first surface of the polishing sub-pad is contacted to the polishing pad and a second surface of the polishing sub-pad is contacted to the polishing platen. One major aspect of this invention is that the first surface or the second surface is undulating.

[0017] In the aforementioned polishing sub-pad, both the first surface and the second surface are undulating.

[0018] This invention also provides a polishing pad for assembling with a polishing platen and a polishing sub-pad to form a polishing element. The polishing pad has a body and one of the surfaces of the polishing pad is boned to the polishing sub-pad. One major aspect of this invention is that the surface is undulating.

[0019] In the aforementioned polishing pad, polishing sub-pad, polishing platen and polishing element, the undulating surface is a structure comprising a plurality of linear grooves and a plurality of protruding spines. Moreover, the grooves are

patterned into various shapes including straights, crosses, concentric circles, spirals or a composite combination of them.

[0020] In addition, in the aforementioned polishing pad, polishing sub-pad, polishing platen and polishing element, the polishing pad is a fixed abrasive polishing pad.

[0021] Because the polishing pad, the polishing sub-pad or the polishing platen has an undulating surface, the polishing pad subjected to pressure will cave in towards the grooves of the undulating surface. Hence, the surface of the polishing pad will be roughened to increase the polishing rate of the polishing element. Even if the surface of the polish object has a planar surface, the polishing element can still provide a relatively high polishing rate.

[0022] Furthermore, the undulation on the surface of the polishing pad is a smooth variation. Hence, the polishing element of this invention not only increases the polishing rate but also reduce the loading effect resulting from a big variation in the density of shallow trench pattern in the substrate.

[0023] Since the polishing element increases the polishing rate and is able to polish objects with a plane surface, thickness of the silicon oxide (the polished material) in the fabrication of shallow trench isolation (STI) structure no longer poses a limitation. In other words, process window for fabricating the STI structure is improved. Furthermore, the lifting of thickness restriction permits the formation of a thicker silicon oxide layer to meet the gap-filling capacity demanded by a miniature STI structure. Thus, the fixed abrasive element of this invention can be applied to fabricated smaller STI structures.

[0024] Aside from increasing the polishing rate of silicon oxide in the fabrication of STI structures, the polishing element of this invention also improves the planarization efficiency in a fixed abrasive chemical-mechanical polishing operation. In particular, the polishing element is able to reduce the amount of dishing of silicon oxide inside the shallow trench and maintain a high polishing selectivity ratio between silicon oxide and silicon nitride.

[0025] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0027] Fig. 1 is a schematic cross-sectional view of a conventional foxed abrasive polishing element.

[0028] Fig. 2 is a schematic cross-sectional view of a polishing element according to a first preferred embodiment of this invention.

[0029] Figs. 3A through 3D are perspective views showing a few possible groove patterns on the polishing element of Fig. 2.

[0030] Fig. 4 is a schematic cross-sectional view showing the polishing element in Fig. 2 polishing a silicon oxide layer on a shallow trench isolation (STI) structure.

[0031] Fig. 5 is a graph showing the effect of using a polishing element with different polishing sub-pad roughness on the oxide/nitride polishing rate.

[0032] Fig. 6 is a schematic cross-sectional view of a polishing element according to a second preferred embodiment of this invention.

[0033] Fig. 7 is a schematic cross-sectional view of a polishing element according to a third preferred embodiment of this invention.

[0034] Fig. 8 is a schematic cross-sectional view of a polishing element according to a fourth preferred embodiment of this invention.

[0035] Fig. 9 is a schematic cross-sectional view of a polishing element according to a fifth preferred embodiment of this invention.

[0036] Fig. 10 is a graph showing the effect of using a polishing element with different polishing platen roughness on the oxide/nitride polishing rate.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0037] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0038] Fig. 2 is a schematic cross-sectional view of a polishing element according to a first preferred embodiment of this invention. As shown in Fig. 2, the polishing element 200 comprises a polishing pad 210, a polishing sub-pad 220 and a polishing platen 230. The polishing pad 210 is set up over the polishing sub-pad 220. In this embodiment, the body of the polishing pad 210 is a fixed abrasive polishing pad, for example. The polishing pad 210 further comprises a plurality of polishing particles

(individual particles are now shown). These polishing particles have triangular, hexagonal or cylindrical shapes and bind with each other to form an array. Each polishing particle comprises a plurality of evenly distributed abrasive particles inside a binder such as a resin. Note that a polishing pad with cerium oxide (CeO_2) particles are preferable used to polish silicon oxide in a shallow trench isolation (STI) structure because cerium oxide has a higher polishing selectivity between silicon oxide and silicon nitride.

[0039] The polishing sub-pad 220 is set up over the polishing platen 230. The body of the polishing sub-pad 220 is made from plastic, rubber or acrylic material. Note that the junction with the polishing pad 210 has a series of protruding structures 224 and grooves 225 to form an undulating surface 222. The undulating surface 222 is formed, for example, by patterning to remove a portion of the polishing sub-pad 220. The grooves 225 may form a pattern having a series of straights (shown in Fig. 3A), a series of crosses (shown in Fig. 3B), a series of concentric circles (shown in Fig. 3C), a spiral pattern (shown in Fig. 3D) or a combination of them.

[0040] The polishing platen 230 is set up over a polishing station (not shown). The body of the polishing platen 230 is fabricated from stainless steel or aluminum alloy, for example.

[0041] Fig. 4 is a schematic cross-sectional view showing the polishing element in Fig. 2 polishing a silicon oxide layer on a shallow trench isolation (STI) structure. As shown in Fig. 4, the wafer 300 has a plurality of STI structures with an undulating filler silicon oxide layer (the polished layer) 310 thereon. To polish the insulation layer 310 using the polishing element 200 according to this embodiment, the surface of

the wafer 300 with the insulation layer 310 thereon is faced down and pressed against the polishing pad 210.

[0042] Note that the polishing pad 210 will cave in a little towards the grooves 225 when subjected to a pressure. Hence, an undulating surface is also reproduced in the polishing pad 210. With a wave-like undulation on the upper surface of the polishing pad 210 as shown in Fig. 4, the protruding portion of the binder in the polishing pad 210 can be easily scrapped away to expose the polishing particles. This facilitates the contact of the polishing particles with the insulation layer 310 and hence increases the polishing rate of the polishing element 200. Furthermore, as the surface of the insulation layer 310 is gradually flattened, the polishing element 200 still continues to provide a relatively high polishing rate because of the undulating polishing pad surface.

[0043] Unlike the surface 222 of the polishing sub-pad 220 that has a sharp right-angled surface variation, the surface undulation (the 'peaks' and the 'valleys') of the polishing pad 210 varies smoothly. Thus, even if the density distribution of the STI structures in the substrate differs considerably, the loading effect of the difference in polishing rate between different regions is minimized.

[0044] Fig. 5 is a graph showing the effect of using a polishing element with different polishing sub-pad roughness on the oxide/nitride removal rate. In Fig. 5, black squares (■) represent the removal rate of a silicon oxide layer using a polishing element with a conventional polishing sub-pad; white squares (□) represent the removal rate of a silicon oxide layer using a polishing element with a grooved polishing sub-pad according to this invention; black circles (●) represent the removal rate of a silicon nitride layer using a polishing element with a conventional polishing sub-pad;

and, white circuits (○) represent the removal rate of a silicon nitride layer using a polishing element with a grooved polishing sub-pad. As shown in Fig. 5, the removal rate for silicon nitride using the polishing element with a conventional polishing sub-pad or the polishing element with a grooved polishing sub-pad is rather low. However, the removal rate for silicon oxide using the polishing element with a grooved polishing sub-pad is considerably higher than using the polishing element with a conventional polishing sub-pad. In other words, the polishing element of this invention effectively increases the removal rate of silicon oxide (the polished material). In particular, the polishing element is suitable for carrying out a chemical-mechanical polishing operation to remove silicon oxide over a silicon nitride layer in the fabrication of STI structures.

[0045] Fig. 6 is a schematic cross-sectional view of a polishing element according to a second preferred embodiment of this invention. In Fig. 6, components identical to the ones in Fig. 2 are labeled identically. As shown in Fig. 6, the polishing element 200 comprises a polishing pad 210, a polishing sub-pad 220 and a polishing platen 230. The second embodiment differs from the first embodiment mainly in that a series of grooves 229 and protruding structures 228 are alternately positioned on the surface 226 of the polishing sub-pad 220 in conjunction with the polishing platen 230. Here, the polishing sub-pad 220 is preferably fabricated using a deformable material such as rubber. Similarly, the grooves 229 on the surface 226 may form a pattern just like the ones shown in Figs. 3A to 3D or any combination of them.

[0046] When a polishing element 200 of this invention is used to carry out a polishing operation, the polishing pad 210 and the polishing sub-pad 220 will cave in a little towards the grooves 229. Hence, an undulating surface is also reproduced in the polishing pad 210. With a wave-like undulation on the upper surface of the polishing

pad 210, polishing rate is increased and loading effect due to pattern density variation is minimized similar to the first embodiment of this invention.

[0047] Fig. 7 is a schematic cross-sectional view of a polishing element according to a third preferred embodiment of this invention. In Fig. 7, components identical to the ones in Fig. 2 are labeled identically. As shown in Fig. 7, the polishing element 200 comprises a polishing pad 210, a polishing sub-pad 220 and a polishing platen 230. The third embodiment differs from the first embodiment mainly in that not only is a series of grooves 225 and protruding structures 224 alternately positioned on the surface 222 of the polishing sub-pad 220 in conjunction with the polishing pad 210, but another series of grooves 229 and protruding structures 228 is also alternatively positioned on the surface 226 of the polishing sub-pad 220 in conjunction with the platen 230. Similarly, the grooves 229 on the surface 226 may form a pattern just like the ones shown in Figs. 3A to 3D or any combination of them.

[0048] When a polishing element 200 of this invention is used to carry out a polishing operation, the polishing pad 210 will cave in a little towards the grooves 225 and the polishing sub-pad 220 will cave in a little towards the grooves 229. Hence, an undulating surface is also reproduced in the polishing pad 210. With a wave-like undulation on the upper surface of the polishing pad 210, polishing rate is increased and loading effect due to pattern density variation is minimized similar to the first embodiment of this invention.

[0049] Fig. 8 is a schematic cross-sectional view of a polishing element according to a fourth preferred embodiment of this invention. In Fig. 8, components identical to the ones in Fig. 2 are labeled identically. As shown in Fig. 8, the polishing element 200 comprises a polishing pad 210, a polishing sub-pad 220 and a polishing

platen 230. The fourth embodiment differs from the first embodiment mainly in that a series of grooves 215 and protruding structures 214 are alternately positioned on the surface 212 of the polishing pad 210 in conjunction with the polishing sub-pad 220. Similarly, the grooves 215 on the surface 212 may form a pattern just like the ones shown in Figs. 3A to 3D or any combination of them.

[0050] When a polishing element 200 of this invention is used to carry out a polishing operation, the polishing pad 210 will cave in a little towards the grooves 215. Hence, an undulating surface is also reproduced in the polishing pad 210. With a wave-like undulation on the upper surface of the polishing pad 210, polishing rate is increased and loading effect due to pattern density variation is minimized similar to the first embodiment of this invention.

[0051] Fig. 9 is a schematic cross-sectional view of a polishing element according to a fifth preferred embodiment of this invention. In Fig. 9, components identical to the ones in Fig. 2 are labeled identically. As shown in Fig. 9, the polishing element 200 comprises a polishing pad 210, a polishing sub-pad 220 and a polishing platen 230. The fifth embodiment differs from the first embodiment mainly in that a series of grooves 235 and protruding structures 234 are alternately positioned on the surface 232 of the polishing platen 230 in conjunction with the polishing sub-pad 220. Here, the polishing sub-pad 220 is preferably fabricated using a deformable material such as rubber. Similarly, the grooves 235 on the surface 232 may form a pattern just like the ones shown in Figs. 3A to 3D or any combination of them.

[0052] When a polishing element 200 of this invention is used to carry out a polishing operation, the polishing pad 210 will cave in a little towards the grooves 235. Hence, an undulating surface is also reproduced in the polishing pad 210. With a

wave-like undulation on the upper surface of the polishing pad 210, polishing rate is increased and loading effect due to pattern density variation is minimized similar to the first embodiment of this invention.

[0053] Fig. 10 is a graph showing the effect of using a polishing element with different polishing platen roughness on the oxide/nitride removal rate. In Fig. 10, black squares (■) represent the removal rate of a silicon oxide layer using a polishing element with a conventional polishing platen (that is, a platen without undulation); white squares (□) represent the removal rate of a silicon oxide layer using a polishing element with a grooved polishing platen according to this invention; black circles (●) represent the removal rate of a silicon nitride layer using a polishing element with a conventional polishing platen; and, white circuits (○) represent the removal rate of a silicon nitride layer using a polishing element with a grooved polishing platen. As shown in Fig. 10, the removal rate for silicon nitride using the polishing element with a conventional polishing platen or the polishing element with a grooved polishing platen is rather low. However, the removal rate for silicon oxide using the polishing element with a grooved polishing platen is considerably higher than using the polishing element with a conventional polishing platen. In other words, the polishing element of this invention effectively increases the removal rate of silicon oxide (the polished material). In particular, the polishing element is suitable for carrying out a chemical-mechanical polishing operation to remove silicon oxide over a silicon nitride layer in the fabrication of STI structures.

[0054] In the aforementioned embodiments, the undulation on the surface of the polishing pad, the polishing sub-pad or the polishing platen is formed by removing a portion of the material to form grooves. However, the process of forming patterns on

the polishing pad, the polishing sub-pad or the polishing platen is not limited as such. For example, adhesive tapes may be attached to the surface of the polishing pad, the polishing sub-pad or the polishing platen. Alternatively, protruding structures are formed on the surface of the polishing pad, the polishing sub-pad or the polishing platen through a screen printing process. In fact, any method capable of forming an undulating pattern on the surface of a polishing pad, a polishing sub-pad or a polishing platen should be included within the scope of this invention.

[0055] Although the fabrication of STI structures is used as illustration in the aforementioned embodiments, other types of processes are also applicable as well. For example, the polishing element of this invention can be used in polishing stations for planarizing wafer surfaces, fabricating of vertical or horizontal interconnects in a damascene process, producing advanced devices, planarizing micro electro-mechanical systems or manufacturing flat display panels.

[0056] In summary, this invention at least includes the following advantages:

1. With undulating pattern formed on the surface of the polishing pad, the polishing sub-pad or the polishing platen, the polishing pad will cave in a little into the grooves to form an undulating surface. Thus, with a wave-like undulation on the upper surface of the polishing pad, the protruding portion of the binder in the polishing pad 210 can be easily scrapped away to expose the polishing particles. This facilitates the contact of the polishing particles with the polished layer and hence increases the polishing rate of the polishing element. Furthermore, as the surface of the polished layer is gradually smoothed out, the polishing element still continues to provide a relatively high polishing rate due to the presence of an undulating polishing pad.

2. The polishing pad of the polishing element has smooth undulating profile. Hence, aside from increasing the polishing rate, loading effect resulting from having a different polishing rate in each region due to pattern density variation is minimized.

3. Because the polishing element of this invention is capable of increasing polishing rate and polishing planar polished objects, thickness of the silicon oxide layer in the fabrication of STI structures no longer present any limitations. In other words, process window for forming STI structures is increased. Furthermore, with thickness limitation of the silicon oxide layer removed, the silicon oxide can be fabricated to whatever thickness to match the gap filling capacity of miniaturized STI structures (feature size smaller than 90nm). Thus, the fixed abrasive polishing element can be applied to fabricate very small STI structures.

4. Aside from increasing the polishing rate of silicon oxide in the fabricated of STI structures, planarization efficiency is also increased via the abrasive chemical-mechanical polishing operation. Furthermore, dishing of the silicon oxide inside the STI is reduced and a high polishing selectivity between silicon oxide and silicon nitride is maintained.

[0057] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.